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PARSONS ENGINEERING SCIENCE, INC.

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October 14, 1997

Major Ed Marchand
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, Texas 78235-5363

Subject: One-Year Testing Results Report for Full-Scale Bioventing at the POL yard, Sites SS-06 and ST-40, Wurtsmith AFB, Michigan
(Contract No. F41624-92-8036, Order 17)

Dear Major Marchand:

This letter report presents the results for the full-scale bioventing system testing performed by Parsons Engineering Science, Inc. (Parsons ES) at the POL yard, Sites SS-06 and ST-40, Wurtsmith AFB, Michigan. Soil gas samples were collected and *in situ* respiration testing was performed by Parsons ES from 15 to 18 September 1997 to assess the extent of remediation completed during approximately 1 year of air injection bioventing. The purpose of this letter is to summarize site and bioventing activities to date, present the results of the most recent respiration testing and soil gas sampling, and make recommendations based on site data. A site layout and two tables are attached. The as-built bioventing system and sampling/respiration testing locations are illustrated on Figure 1. Table 1 provides results of initial and 1-year soil gas sampling, and Table 2 provides results of respiration testing performed both prior to bioventing system startup and after 1-year of air injection bioventing.

SITE/PROJECT HISTORY

Wurtsmith AFB is presently undergoing closure activities, and Site SS-06, a former POL bulk storage facility at the Base, is vacant and inactive. All four aboveground fuel storage tanks (ASTs) and two underground storage tanks (USTs), which contained JP-4 jet fuel, have been removed. The pilot test area is located near the former location of Tank 7000. The layout of Site SS-06 is shown on Figure 1. A groundwater pump-and-treat system (referred to as the benzene plant), located approximately 400 feet northeast of the POL Yard, was installed to treat groundwater contaminated with benzene, toluene, ethylbenzene, xylenes (BTEX), and a free product plume originating at the POL Yard.

The primary soil contaminants at this site are fuel-related petroleum hydrocarbons, which have been detected in the soil gas, soils, and groundwater. The source of the hydrocarbon contamination is thought to be leaks from the former JP-4 tanks and underground JP-4 pipelines.

AQM01-02-0397

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In July 1994, a passive soil gas survey was conducted by ICF Technology (1995) to determine the extent of JP-4 contamination in the soils at the POL yard. The survey was conducted by installing sorbent collection devices at 83 locations within and adjacent to the POL yard. Soil gas results from the ICF Technology survey indicated high concentrations of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) within the bermed area, immediately adjacent to the former location of Tank 7000.

Soil samples were collected from 12 soil borings within and adjacent to the POL yard in 1995 to determine the extent of soil contamination beneath the site (ICF Technology, 1995). Petroleum hydrocarbon contamination detected in these soils exceeded state soil criteria for groundwater protection, or 20 times the appropriate state drinking water value (Michigan Department of Environmental Quality [MDEQ], 1995a and 1995b). Total xylenes and naphthalene were detected in soil samples at maximum concentrations of 50,000 micrograms per kilogram (µg/kg), and 6,400 µg/kg, respectively. Michigan soil cleanup criteria for total xylenes is 5,600 µg/kg for commercial/industrial and residential sites. Soil cleanup criteria for naphthalene differ for commercial/industrial and residential sites. The maximum detected concentrations of naphthalene in soil at Site SS-06 are below the commercial/industrial site criteria of 15,000 µg/kg, but above the residential site criteria of 5,200 µg/kg. Ethylbenzene, toluene, acenaphthalene, fluorene, phenanthrene, and pyrene also were detected in the soil at concentrations below the industrial cleanup criteria. Additionally, benzene was identified as the primary constituent of concern in a groundwater contaminant plume that originates beneath Site SS-06 (ICF Technology, 1995).

Additional soil gas samples were collected by Parsons ES in September 1995 and field-analyzed to determine whether or not the soil gas beneath the site was oxygen depleted. Soil gas samples were collected from two wells on the north side of the bermed area and from one well on the east side of the bermed area. Oxygen concentrations in soil gas ranged from 1.0 to 7.5 percent. Total volatile hydrocarbon (TVH) concentrations in soil gas ranged from 2,400 parts per million, volume per volume (ppmv) to over 20,000 ppmv. Low oxygen concentrations in soil gas indicated that soil microbes are consuming oxygen faster than it can naturally diffuse into the soils, and that air (oxygen) injection would enhance the rate of fuel hydrocarbon biodegradation. Based on previous soil sampling results and the September 1995 soil gas screening results, Air Force Center for Environmental Excellence (AFCEE) determined that a bioventing pilot test should be conducted to determine the feasibility of using bioventing to remediate site soils.

In July 1996, a pilot-scale bioventing system was installed and tested at Site SS-06 by Parsons ES as part of the AFCEE Extended Bioventing program (Contract No. F41624-92-D-8036, Order 17). Under this program, Site SS-06 was funded for pilot-scale bioventing system installation and testing, and full-scale system installation (under two Option 3's); two years of extended system operation with maintenance and monitoring (under two Option 1's); and, if 2-year extended bioventing testing results

indicate adequate site remediation, completion of confirmatory soil sampling and site closure documents (Option 2).

Following the successful testing of the pilot-scale bioventing system, a full-scale system was designed and installed in July and August 1996. The full-scale bioventing system is shown in Figure 1. The full-scale bioventing system consists of eight vent wells (VWs), nine vapor monitoring points (MPs), and a blower unit. During installation of the pilot-scale system, respiration and air permeability testing and soil and soil gas sampling were performed. Based on oxygen influence and air permeability testing performed during installation of the pilot-scale system, the long-term radius of oxygen influence was expected to exceed 65 feet at depths between 5 and 14 feet bgs (bgs) and 100 feet at depths between 14 and 20 feet bgs. A detailed description of the bioventing system design and initial site activities are provided in the *Bioventing Pilot Test Results and Full-Scale System Installation Report for POL Yard, Sites SS-06 and ST-40* (Parsons ES, 1996).

Following completion of full-scale system installation and testing, the system was started, optimized, and operated continuously until August 1997. In August, the system was shut down for 36 days to allow soils and soil gas to reach equilibrium in order to compare initial and 1-year conditions. Soil gas samples were collected and *in situ* respiration testing was performed from 15 through 18 September 1997, following the 36-day shutdown period. The blower system was restarted following 1-year testing to continue bioventing treatment of site soils. Results of the 1-year soil gas sampling and respiration testing are presented in the following sections.

SOIL GAS CHEMISTRY RESULTS

Field screening and collection of soil gas samples for laboratory analyses were performed from 15 through 17 September 1997, following approximately 1 month of system shutdown. Soil gas samples were collected from the VWs, each MP screened interval, and groundwater monitoring wells MW-A64 and MW-A66. These samples were field-screened to assess soil gas concentrations of oxygen, carbon dioxide, and total volatile hydrocarbons (TVH). As can be seen from the results presented in Table 1, soil gas field TVH measurements and laboratory results have decreased significantly at most locations as the result of one year of full-scale bioventing system operation.

Static oxygen concentrations in soil gas samples collected from three of the VWs (VW-2, VW-3, and VW-6) have increased considerably with continued bioventing at the site, while static oxygen concentrations have remained at or less than 0.5 percent at VW-1, VW-4, VW-5, and all MPs (Table 1). One-year oxygen concentrations at VW-7 and VW-8 were 8.5 and 7.0 percent, respectively; these concentrations are basically the same as initial conditions and reflect the fact that fuel contamination in these locations is limited to a thin smear zone associated with the groundwater surface. Depleted soil gas oxygen concentrations measured at most locations indicate that aerobic hydrocarbon biodegradation rates remain relatively high and exceed the rate at which oxygen can naturally diffuse into the soils from the ground surface and adjacent

uncontaminated areas. Natural diffusion of oxygen into the soils is greatly restricted at this site because of the impermeable liners covering most of the site. These results suggest that significant substrate (total fuel hydrocarbons) remains in unsaturated site soils.

Although soil gas field screening results for oxygen suggest that significant concentrations of biodegradable fuel hydrocarbons remain in site soils, soil gas field TVH measurements and laboratory results for TVH and BTEX indicate a substantial reduction of residual fuel hydrocarbons in soils at most locations following 1 year of bioventing system operation. Soil gas field TVH screening results presented in Table 1 indicate a 1 to 2 order of magnitude reduction at 9 of 24 VW and MP locations, less than 1 order of magnitude reduction at 10 locations, and an increase at 2 locations (MPD-12 and MPI-18). Comparison between initial and 1-year data for 3 locations (VW-2, MPD-18, and MPF-20) could not be made due to insufficient data. Soil gas samples for laboratory analysis were collected at 8 locations before bioventing system startup (initial) and at 8 locations following 1 year of system operation (1-year). Six of the 8 sample locations were the same for the initial and 1-year sampling events. For both sampling events, samples were sent to the Air Toxics, Ltd. laboratory in Folsom, California and analyzed for TVH and BTEX using United States Environmental Protection Agency (USEPA) Method TO-3. As can be seen from the results at MPA-11, MPB-18, MPC-5, MPC-18, and MPG-18, total BTEX and TVH concentrations in soil gas were reduced between approximately 40 and 99 percent during the first year of system operation. The only exception to the trend of reduced TVH and BTEX levels was the result for MPI-18, which showed an increase in TVH concentration (15,000 to 32,000) and a slight increase in total BTEX concentration (190 to 197 ppmv) after one year of system operation. Although an overall decrease in total BTEX concentration was observed, results for xylenes indicate increased concentrations of this compound at 4 locations (MPB-18, MPC-18, MPG-18, and MPI-18). The apparent increase in xylenes at three of these locations may be the result of the 1-year laboratory-reported values being biased due to matrix interference. Field and analytical soil gas results suggest a significant degree of remediation of hydrocarbon contaminants in the unsaturated soils at Site SS-06. However, these results also indicate that sufficient fuel hydrocarbons remain in unsaturated soils to warrant continued bioventing treatment.

An oxygen concentration of 20.5 percent was measured in soil gas from the background monitoring point (groundwater monitoring well W-416), which is installed in similar but uncontaminated soil. The high oxygen level measured at the background location (measured during initial bioventing pilot testing in July 1996) indicates that biological oxygen consumption of natural (nonfuel) organic carbon and abiotic oxygen consumption did not occur in these soils. Therefore the biological oxygen consumption measured at Site SS-06 is predominantly the result of biological consumption of oxygen during biodegradation of fuel hydrocarbons.

IN SITU RESPIRATION TEST RESULTS

In situ respiration (oxygen utilization) testing was performed at the POL Yard from 16 through 18 September 1997. The testing was performed according to protocol procedures (Hinchee *et al.*, 1992) and followed 36 days of bioventing system shutdown. Air was injected for 21 hours into MPA-11, MPC-12, MPC-18, and MPE-18; and for 24 hours into MPG-18 and MPH-18; using 1 cubic-foot-per-minute (cfm) pumps, to locally oxygenate site soils. Following air injection, changes in oxygen, carbon dioxide, and TVH soil gas concentrations were monitored over a 47-hour period at MPA-11, MPC-12, MPC-18, and MPE-18; and over a 23-hour period for MPG-18 and MPH-18. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates at Site SS-06. Table 2 summarizes initial and 1-year respiration and fuel biodegradation rates at the site.

Observed oxygen utilization and calculated fuel biodegradation rates have decreased at two locations (MPA-11 and MPE-18) and increased at two locations (MPC-12 and MPC-18) following one year of bioventing system operation. Although the results were mixed, the average rates for these four locations decreased approximately 25 percent compared with the initial rates. Initial respiration testing was not performed at MPG and MPH, so comparisons with the one-year rates cannot be made for these locations. However, 1-year respiration and biodegradation rates determined for MPG and MPH were similar to the rates observed at other locations at the site.

Oxygen utilization and fuel biodegradation rates typically decrease with continued bioventing as the lighter, more readily biodegraded hydrocarbons are preferentially destroyed over more biologically recalcitrant, higher molecular weight hydrocarbons. As demonstrated by the soil gas results presented in Table 1 and *in situ* respiration testing results presented in Table 2, fuel hydrocarbon concentrations have been significantly reduced, but sufficient hydrocarbons remain in the unsaturated soils to sustain moderate respiration rates.

CONCLUSIONS AND RECOMMENDATIONS

Based on initial soil sampling results and soil gas and respiration testing results obtained prior to and following one year of full-scale bioventing system operation, fuel hydrocarbons in the unsaturated soil at Site SS-06 have been greatly reduced, but significant concentrations of aerobically biodegradable fuel hydrocarbons remain in site soils. Therefore, Parsons ES recommends operating the bioventing system for an additional year to further remediate site soils prior to initiating closure soil sampling activities.

Parsons ES is currently under contract with AFCEE to provide one additional year of system operation, maintenance, and *in situ* respiration testing/soil gas sampling (Option 1), and to perform confirmation soil sampling and prepare a closure report (Option 2) for Site SS-06. The additional one-year period of performance for the Option 1 task began on 18 September 1997 and will end on 18 September 1998. After

the one additional year of system operation, the system will be turned off for approximately one month, followed by an additional Option 1 respiration testing/soil gas sampling event. Option 2 site closure activities will be performed if two-year testing/soil gas sampling results indicate that soils have been sufficiently remediated to meet MDEQ soil cleanup criteria.

If you have any questions or require additional information, please contact either John Hall at (970) 244-8829 or John Ratz at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

David Tut for JFH

John F. Hall, P.E.
Site Manager

John W. Ratz

John W. Ratz, P.E.
Project Manager

Attachments: Figure 1, Tables 1 and 2

cc: Mr. Paul Rekowski, Wurtsmith AFBCA
File 726876.69110 Letter Results Report

REFERENCES

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frendt. 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing. Prepared for USAF Center for Environmental Excellence. May.

ICF Technology, Inc. 1995. *The United States Air Force Installation Restoration Program Site Characterization Summary, Sites SS-06, SS-13, and SS-40.* March.

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Michigan Department of Environmental Quality (MDEQ). 1995b. *Interim Environmental Response Division Operational Memorandum # 14, Revision 2: Remedial Action Plans Using Generic Industrial or Generic Commercial Cleanup Criteria and Other Requirements.* June 6.

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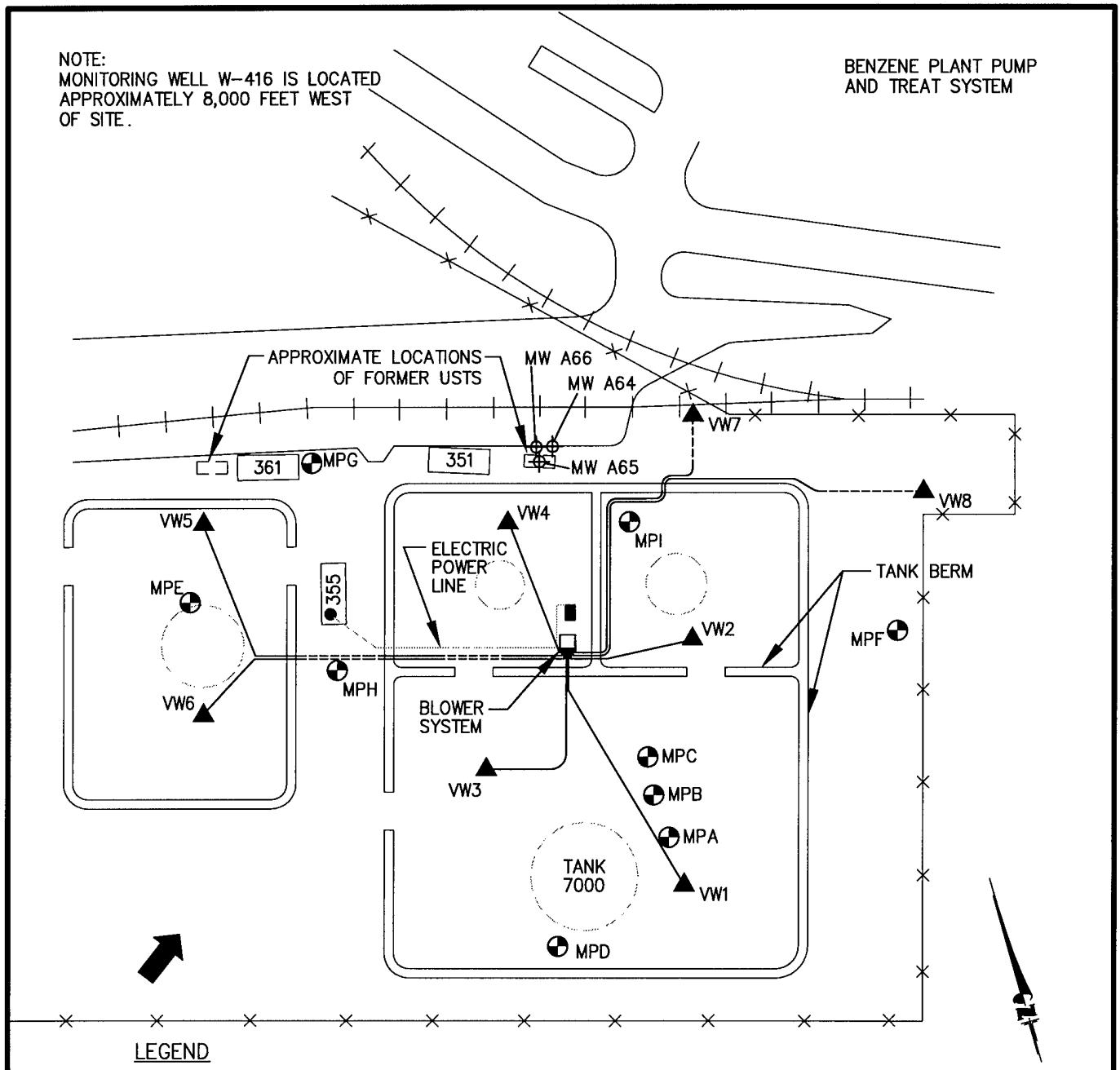

LEGEND

- CHAIN LINK FENCE
- GROUNDWATER FLOW DIRECTION
- VW3 ▲ AIR INJECTION WELL
- MPA ⊕ VAPOR MONITORING POINT
- MW A65 ⊕ GROUNDWATER MONITORING WELL
- AIR PIPELINE, DASHED WHERE BURIED
- FORMER AST LOCATION
- EXISTING ELECTRICAL DISTRIBUTION PANEL AND NEW ELECTRIC METER
- NEW ELECTRICAL DISTRIBUTION PANEL AND MOTOR STARTER

0 50 100 200

Approximate Scale In Feet

FIGURE 1

AS-BUILT FULL-SCALE BIOVENTING SYSTEM LAYOUT

Sites SS-06 and ST-40
Wurtsmith AFB, Michigan

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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TABLE 1
INITIAL AND 1-YEAR SOIL GAS FIELD AND LABORATORY ANALYTICAL RESULTS
POL YARD, SITES SS-06 AND ST-40
Wurtsmith AFB, Michigan

			Field Screening Data			Laboratory Analytical Data[a/]					
Sampling Location	Screen Depth (ft bgs)[c/]	Sampling Event[d/]	Oxygen (percent)	Carbon Dioxide (percent)	TVH[b/] (ppmv)[e/]	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethyl-benzene (ppmv)	Xylenes (ppmv)	Total BTEX (ppmv)
VW-1	7-22	Initial	0.0	12.1	> 20,000	----[f/]	----	----	----	----	----
		1-Year	0.0	10.8	17,000	----	----	----	----	----	----
VW-2	7-22	Initial	0.0	14.2	8,000	----	----	----	----	----	----
		1-Year	1.8	9.0	----[g/]	----	----	----	----	----	----
VW-3	7-22	Initial	0.0	13.0	5,600	----	----	----	----	----	----
		1-Year	5.0	7.0	320	----	----	----	----	----	----
VW-4	8-23	Initial	0.0	8.8	> 20,000	----	----	----	----	----	----
		1-Year	0.5	4.5	340	----	----	----	----	----	----
VW-5	8-23	Initial	0.0	12.6	> 20,000	----	----	----	----	----	----
		1-Year	0.0	9.5	2,000	----	----	----	----	----	----
VW-6	8-23	Initial	0.0	13.4	11,200	----	----	----	----	----	----
		1-Year	8.9	3.5	400	----	----	----	----	----	----
VW-7	13-23	Initial	7.8	7.5	4,600	----	----	----	----	----	----
		1-Year	8.5	6.2	260	----	----	----	----	----	----
VW-8	14-24	Initial	6.8	9.2	2,400	----	----	----	----	----	----
		1-Year	7.0	7.6	1,120	----	----	----	----	----	----
MPA	5	Initial	0.0	12.2	17,200	----	----	----	----	----	----
		1-Year	0.0	10.8	440	----	----	----	----	----	----
MPA	11	Initial	0.0	12.0	> 20,000	22,000	69 M[h/]	100	31	65	265
		1-Year	0.0	10.9	5,000	1,500	< 0.11	.37	0.25 M	1.4 M	2.02
MPA	18	Initial	0.0	12.3	> 20,000	----	----	----	----	----	----
		1-Year	0.0	10.6	9,800	----	----	----	----	----	----
MPB	5	Initial	2.0	10.2	17,600	----	----	----	----	----	----
		1-Year	0.5	10.5	280	----	----	----	----	----	----
MPB	12	Initial	0.0	12.0	> 20,000	----	----	----	----	----	----
		1-Year	0.0	11.4	1,780	----	----	----	----	----	----
MPB	18	Initial	0.0	12.1	> 20,000	25,000	70	110	33	76	289
		1-Year	0.0	11.5	16,000	7,100	< 0.53	11	23	130	164

TABLE 1 (Continued)
INITIAL AND 1-YEAR SOIL GAS FIELD AND LABORATORY ANALYTICAL RESULTS
POL YARD, SITES SS-06 AND ST-40
Wurtsmith AFB, Michigan

			Field Screening Data			Laboratory Analytical Data[a/]					
Sampling Location	Screen Depth (ft bgs)[c/]	Sampling Event[d/]	Oxygen (percent)	Carbon Dioxide (percent)	TVH[b/] (ppmv)[e/]	TVH (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethyl-benzene (ppmv)	Xylenes (ppmv)	Total BTEX (ppmv)
MPC	5	Initial	0.0	11.2	> 20,000	24,000	58	120	32	70	280
		1-Year	0.0	12.0	1,240	570	< 0.11	1.7	1.3	3.3	6.3
MPC	12	Initial	0.0	11.0	19,200	----	----	----	----	----	----
		1-Year	0.0	12.5	5,600	----	----	----	----	----	----
MPC	18	Initial	0.0	11.0	> 20,000	20,000	57	94	26	58	235
		1-Year	0.0	12.8	19,200	11,000	< 1.1	25 M	12	64 M	101
MPD	12	Initial	0.0	13.1	6,000	----	----	----	----	----	----
		1-Year	0.0	14.5	10,400	11,000	< 1.1	23 M	14	58	95
MPD	18	Initial	0.0	13.2	4,000	16,000	38	99	34	40	211
		1-Year	NS[i/]	NS	NS	----	----	----	----	----	----
MPE	18	Initial	0.0	11.2	> 20,000	----	----	----	----	----	----
		1-Year	0.0	10.7	4,000	6,300	< 2.66	12	20	130 M	162
MPF	20	Initial	0.0	13.8	3,600	----	----	----	----	----	----
		1-Year	NS	NS	NS	----	----	----	----	----	----
MPG	18	Initial	0.0	10.4	> 20,000	38,000[i/]	145[j/] M	96[j/]	30[j/]	54[j/]	325
		1-Year	0.0	14.0	16,400	18,000	< 1.1	61 M	23 M	110 M	194
MPH	18	Initial	0.0	7.8	19,600	21,000	43	61	14	26	144
		1-Year	0.4	14.0	4,000	----	----	----	----	----	----
MPI	18	Initial	0.0	13.8	9,800	15,000	55	81	20	34	190
		1-Year	0.0	15.0	19,200	32,000	< 5.4	41 M	26	130 M	197
MW-A64	N/A[k/]	Initial	1.0	---	> 20,000	----	----	----	----	----	----
		1-Year	0.0	14.0	16,400	----	----	----	----	----	----
MW-A66	N/A[k/]	Initial	NS	---	NS	----	----	----	----	----	----
		1-Year	0.0	15.2	> 20,000	----	----	----	----	----	----
W-416 (Background)	8-18	Initial	20.5	0.7	16	----	----	----	----	----	----
		1-Year	---	---	---	----	----	----	----	----	----

TABLE 1 (Continued)
INITIAL AND 1-YEAR SOIL GAS FIELD AND LABORATORY ANALYTICAL RESULTS
POL YARD, SITES SS-06 AND ST-40
Wurtsmith AFB, Michigan

[a/] Laboratory analysis of soil gas performed using USEPA Method TO-3. Laboratory TVH referenced to jet fuel (MW=156).
[b/] TVH = total volatile hydrocarbons.
[c/] ft bgs = feet below ground surface.
[d/] Soil gas sampling performed in July and August 1996 (initial), and September 1997 (1-year).
[e/] ppmv = parts per million, volume per volume.
[f/] --- = not analyzed.
[g/] Field TVH measurement not documented in the field book.
[h/] M = Laboratory reported value may be biased due to apparent matrix interferences.
[i/] NS = No sample collected; MP was flooded.
[j/] Result averaged with duplicate sample result.
[k/] N/A = Information not available.

TABLE 2
INITIAL AND 1-YEAR RESPIRATION AND BIODEGRADATION RATES
POL YARD, SITES SS-06 AND ST-40
Wurtsmith AFB, Michigan

	Initial (August 1996)			1-Year (September 1997)		
Location-Depth[a/]	O_2 Utilization Rate (K_0) (% O_2/hr)[b/]	Biodegradation Rate[c/] (mg/kg/year)[d/]	Soil Temperature (°C)	O_2 Utilization Rate (K_0) (% O_2/hr)	Biodegradation Rate[c/] (mg/kg/year)	Soil Temperature (°C)
MPA-5	----[e/]	----	8.3	----	----	16.9
MPA-11	0.45	2,500	----	0.31	1,710	----
MPA-18	0.08	400	16.6	----	----	13.1
MPC-12	0.15	820	----	0.19	1,080	----
MPC-18	0.15	780	----	0.18	1,000	----
MPE-18	0.44	2,100	----	0.19	930	----
MPG-18	----	----	----	0.40	1,910	----
MPH-18	----	----	----	0.35	1,680	----

[a/] Location-Depth gives screened interval location and depth below ground surface (bgs).

[b/] % O_2/hr = percent oxygen per hour.

[c/] Initial and 1-year biodegradation rates based on moisture content of the soil during initial sampling. 1-year soil sampling was not performed.

[d/] mg/kg/year = milligrams of hydrocarbons per kilogram of soil per year.

[e/] ---- = not measured or not calculated.